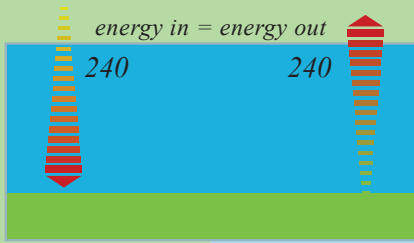


# CO<sub>2</sub> Forcing and Response

Over long time scales, the Earth is in equilibrium with its space environment.

## Panel 1



$$T_s = 15\text{ C } (\sim 59\text{ F})$$

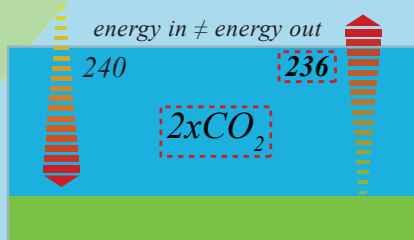
### Starting Point:

Earth at equilibrium with net energy input from the Sun.

Average surface temperature 15 C (~59 F)

Earth's temperature has averaged 15 C (~59 F), with a balance of 240 W/m<sup>2</sup> of energy being absorbed from the Sun; and 240 W/m<sup>2</sup> being emitted to space as heat energy.

## Panel 2



$$T_s = 15\text{ C } (\sim 59\text{ F})$$

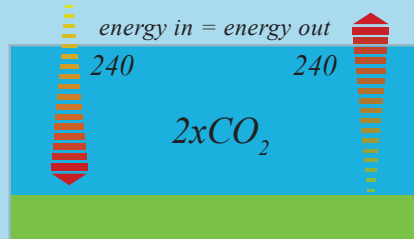
### The Experiment:

Instantaneously double CO<sub>2</sub> in concentration in atmosphere

Average energy emitted by Earth drops 4 W/m<sup>2</sup> (236 vs 240) because of additional energy absorption by CO<sub>2</sub>

Using well understood physics, we can explore what happens if the concentration of carbon dioxide (CO<sub>2</sub>) in the atmosphere doubles. Since CO<sub>2</sub> retains heat, the immediate effect is a small reduction in the amount of heat emitted to space – an imbalance.

## Panel 3



$$\Delta T_{s,d} = 1.2\text{ C } (\sim 2.1\text{ F})$$

### Response:

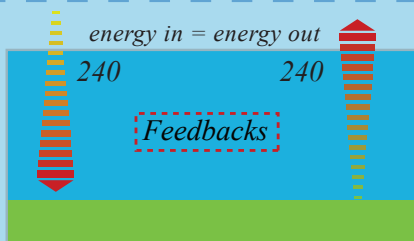
All other things being equal, simple physics theory says:

Average surface temperature rises 1.2 C (~2.1 F)

Energy back in balance

To return to equilibrium, Earth's average surface temperature would increase by 1.2 C to 16.2 C (61.2 F) in order to emit more heat and return to balance with the Sun.

## Panel 4



$$\Delta T_s = 2.0 - 4.5\text{ C } (\sim 3.6 - 8\text{ F})$$

### Feedbacks:

In the Earth system, other processes kick in (water vapor feedback, cloud feedback, ice-albedo feedback, etc).

Net effect: Average surface temperature estimated to rise 2 - 4.5 C (~3.6 - 8 F)

However, the Earth is not quite that simple: rising temperatures have other effects, like increasing water vapor (a greenhouse gas) in the atmosphere, melting ice sheets (which reflect sunlight) and changing cloudiness. While not entirely understood, these feedbacks amplify the temperature rise to return to equilibrium. Scientists estimate the Earth's average temperature would actually rise between 2 and 4.5 C (3.5 and 8 F) before equilibrium was restored.

\*Indicates a change has occurred